Contrib. Astron. Obs. Skalnaté Pleso **49**, 367 – 372, (2019)

Photometric observations of the asteroid 3200 Phaethon using small and middle telescopes

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Received: November 2, 2018; Accepted: March 28, 2019

Abstract. The main aim of photometrical observations of the asteroid 3200 Phaethon was searching for its low-level cometary activity (possible coma and/or dust tail) in the pre-perihelion passage. We performed observational runs with telescopes ranging from 0.61-m to 2-m and BVR color imaging. Three longer photometric series were used for modeling of the 3D shape of Phaethon. The color indices and size of the asteroid were estimated.

Key words: asteroids – 3200 Phaethon – photometry

1. Introduction

Near-Earth asteroid 3200 Phaethon is an outstanding small body in the Solar System. Its perihelion distance is 0.14 au, quite close to the Sun, and leads to a systematic strong heating of the surface. Phaethon reveals cometary activity (Jewitt, 2012), and is considered as a parent body of the Geminid meteor shower (Williams & Wu, 1993; Ryabova et al., 2019). These three features make Phaethon a legitimate target for space-probe exploration (Arai, 2018).

2. Results from photometry

Observations of the asteroid 3200 Phaethon were obtained from October to December 2017 with the 2-m telescope at the Terskol Observatory (Caucasus, Russia), the 1-m telescope at the Sanglokh Observatory (Tajikistan), and the 0.61-m telescope at the Skalnaté Pleso Observatory (Slovakia). The photometric data were obtained through the B, V, and R broadband filters. The reduction of the raw data using bias subtraction, dark and flat field correction was applied in a standard way. The color indices, absolute magnitude, and effective diameter of the asteroid with uncertainties one can see in Tab. 1. For calculation of the effective diameter we applied the formula

$$\log p_V = 6.259 - 2\log D - 0.4H, \tag{1}$$

where D is the diameter of the asteroid in kilometers, p_V the geometric albedo, and H the absolute V-band magnitude (Bowell et al., 1989).

Table 1. Photometric results of 3200 Phaethon from October to December 2017. Table contains heliocentric and geocentric distances and the solar phase angle, respectively. Then color indices, the absolute magnitude, and the effective diameter of the asteroid with uncertainties. For all diameter estimates we used the value of albedo of 0.1066 (Tedesco et al., 2004). In the last column there are listed the acronyms for Sanglokh, Skalnaté Pleso, and Terskol, respectively.

Date	r	Δ	α	$B-V$	$V-R$	H	D	Obs.
	au	au	deg	mag	mag	mag	km	
Oct 28	1.640	0.977	34.0	0.69	0.35	14.37	5.52	San
				±0.07	±0.04	±0.03	±0.08	
Oct 29	1.630	0.957	34.0	0.66	0.36	14.35	5.57	San
				±0.13	±0.06	±0.09	±0.22	
Nov 15	1.444	0.603	32.4	–	0.43	14.42	5.38	SPO
				–	±0.02	±0.03	±0.08	
Nov 17	1.422	0.566	31.9	0.59	0.43	14.40	5.43	San
				±0.11	±0.07	±0.06	±0.15	
Nov 22	1.357	0.461	30.4	0.62	0.35	14.36	5.54	SPO
				±0.02	±0.02	±0.02	±0.05	
Nov 23	1.346	0.443	30.1	0.64	0.36	14.37	5.50	SPO
				±0.04	±0.03	±0.04	±0.09	
Nov 27	1.294	0.367	28.3	0.65	0.33	14.35	5.58	SPO
				±0.02	±0.02	±0.02	±0.05	
Dec 02	1.226	0.273	25.0	0.65	0.35	14.33	5.62	Ter
				±0.01	±0.01	±0.01	±0.02	
Dec 13	1.061	0.089	29.6	0.63	0.35	14.22	5.92	Ter
				±0.01	±0.02	±0.02	±0.06	

For comparison our results with other authors we can use the ALCDEF database[1]. Color indices we can compare with values from papers of Pan et al. (2012), Jewitt (2013), and Ansdell et al. (2014). Our determined colors are in

[1] http://alcdef.org/

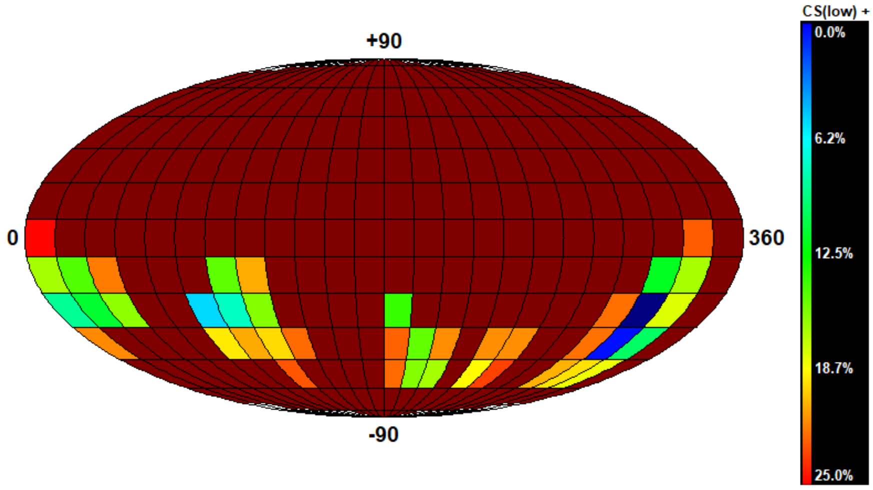

Figure 1. χ^2 residuals between the synthetic and observed lightcurves of the asteroid for spin-vector coordinates covering the entire celestial sphere. The dark blue region represents the pole location with the lowest χ^2, which increases as the color goes from green to yellow and, finally, to red.

good agreement with published values. Absolute magnitudes H have been published by many authors. The values are in the interval from 13.96 to 14.60 mag, but only one is reviewed with three decimal places. It is value 14.345 mag (Pravec et al., 2012). Our H values determined in all nights are very similar to that value.

Also we derived a convex 3D shape model of Phaethon based on 51 previously published in the DAMIT database (Hanuš et al., 2016) and our 3 lightcurves

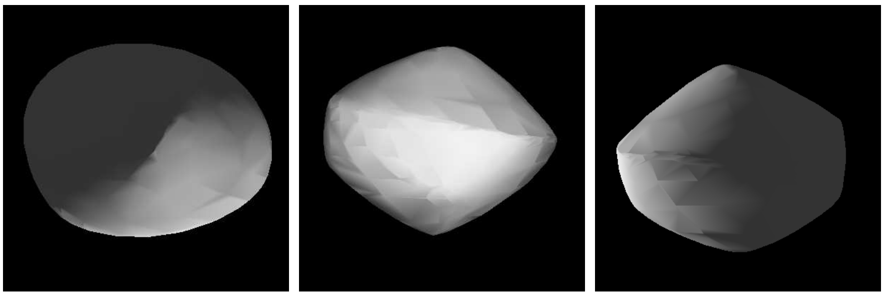

Figure 2. The 3D shape model of Phaethon. On the left there is shown a north pole view, in the middle and right the equatorial viewing and illumination geometry with rotational phases 90° apart.

(November 22 and 27, and December 02, 2017). We have used the robust method, the so-called lightcurve inversion described by Kaasalainen & Torppa (2001) and Kaasalainen et al. (2001). It allows us to determine the sidereal period and pole solutions and recover a detailed convex 3D shape model. The sidereal rotational period was estimated at the value of $3.603\,96 \pm 0.000\,01$ hr. This value is almost the same as computed by Hanuš et al. (2016) and reviewed in the ALCDEF database.

Next, the north pole coordinates were computed. In Fig. 1 there is shown the possible location of the north pole at the ecliptic longitude $\lambda_{\rm p} = 315^\circ \pm 10^\circ$ and latitude $\beta_{\rm p} = -31^\circ \pm 10^\circ$. From that it follows that the sense of rotation of Phaethon is retrograde. The first estimates of the spin axis orientation were published by Krugly et al. (2002) and Ansdell et al. (2014), but the currently accepted, most probable value is that of Hanuš et al. (2016). Our estimate is very similar. The latest published position of the north pole of Phaethon at $(318^\circ \pm 5^\circ, -47^\circ \pm 5^\circ)$ is from the article by Hanuš et al. (2018). Our determined 3D shape model has the ratios at $a/b = 1.11$ and $b/c = 1.04$ (Fig. 2), but that we cannot compare with data from the ALCDEF database.

3. Conclusion

Despite many attempts to obtain signs of Phaethon's cometary activity, no trace of it has been detected. But our photometry in all observed nights showed that Phaethon should be actually larger than 5.1 km as it was previously published. The analysis from the Arecibo radar confirmed that Phaethon is really larger and has the diameter of approx. 6 km (Taylor et al., 2018) and an almost spherical 3D shape[2]. Results of multi-color photometry show a bluish surface for Phaethon. It is in contrast with typical cometary nuclei that are slightly reddish in general (Tedesco & Desert, 2002). Zheltobryukhov et al. (2018) estimated the geometric albedo of Phaethon to be 0.075 ± 0.007 in the R filter, which appears to be consistent with dark F-type asteroids. Also our data confirmed the taxonomy F-type of Phaethon. Note that Phaethon was classified as Tholen F-type by Tholen (1984).

Acknowledgements. AK thanks for the support, in part, from the RFBR grant No. 16-02-00805-a. OI is supported, in part, by the project the SASPRO Program, REA grant agreement No. 609427, and the Slovak Academy of Sciences (Grant Vega No. 2/0023/18). MH thanks Grant VEGA No. 2/0023/18. Observations at the Skalnaté Pleso Observatory were acquired under the realisation of the project ITMS No. 26220120029, based on the supporting operational Research and development program financed from the European Regional Development Fund.

[2]https://www.jpl.nasa.gov/news/news.php?feature=7030

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